Contents

Preface viii

SECTION I. GROWTH MECHANISMS AND MATERIAL ASPECTS

Fundamentals of surface step and island formation mechanisms
B.S. Swartzentruber 1

A modified BCF model to quantitatively describe the (1 0 0)InP growth rate in chemical beam epitaxy
C.A. Verschuren, M.R. Leys, T. Marschner, H. Vonk and J.H. Wolter 11

MOMBE growth of InGaP on (1 0 0) and (4 1 1)A GaAs substrates using tertiarybutylphosphine (TBP)
S. Hatatani, K. Yuasa and M. Konagai 17

A comparison of the transitory periods in GaAs and AlGaAs CBE growth
D. Hill, T. Farrell, T.B. Joyce and T.J. Bullough 21

Striation development in CBE-grown vicinal plane InGaAs layers
K.P. Giannakopoulos and P.J. Goodhew 26

MOMBE and characterization of InAs and (Al,Ga)Sb
Ch. Ungermanns, H. Hardtdegen, M. Matt, A. Förster, M.v.d. Ahe, R. Carius, R. Schmidt and H. Lüth 32

Low-temperature laser assisted CBE-growth of AlGaAs
R. Jothilingam, T. Farrell, T.B. Joyce and P.J. Goodhew 39

Low-resistance polycrystalline GaAs grown by gas-source molecular beam epitaxy using CBr_4
N.Y. Li and C.W. Tu 45

Doping of InSb and InAs using CBr_4 during growth by gas source molecular beam epitaxy
W. Schoenfeld, M.J. Antonell and C.R. Abernathy 50

Highly carbon-doped $Ga_{0.47}In_{0.53}As$ contact layers grown by using carbontetrabromide in MBE on MOVPE 1.55 μm GaInAsP/InP MQW laser structures
J.M. Schneider, K. Bitzer, J. Rieger and H. Heinecke 56

Flux monitoring and control in epitaxy by chemical vapor deposition
T.P. Pearsall, N. Brown, N.L. Ricker and M. Johnson 63

A thermodynamic analysis of the growth of III–V compounds with two volatile group V elements by molecular-beam epitaxy
A.Yu. Egorov, A.R. Kovsh, V.M. Ustinov, A.E. Zhukov, P.S. Kop'ev and C.W. Tu 69

SECTION II. NEW MATERIALS AND NITRIDES

Nitridation of $In_xGa_{1-x}As$ by dimethyl-hydrazine (DMHy)
A. Hashimoto, Y. Aiba, Y. Kurumi and A. Yamamoto 75

Comparison between monomethyl hydrazine and ECR plasma activated nitrogen as a nitrogen source for CBE growth of GaN
S. Yonemura, T. Yaguchi, H. Tsuchiya, N. Shimoyama, T. Suemasu and F. Hasegawa 81

Chemical beam epitaxy of GaN using triethylgallium and ammonia
X.Q. Shen, S. Tanaka, S. Iwai and Y. Aoyagi 86

GaN growth on sapphire and 6H-SiC by metalorganic molecular beam epitaxy
M. Yoshimoto, A. Hatanaka, H. Itoh and H. Matsunami 92

Strong photoluminescence emission from GaN grown on amorphous silica substrates by gas source MBE
K. Iwata, H. Asahi, K. Asami, R. Kuroiwa and S. Gonda 98

Band gap energy of GaNAs grown on GaAs(0 0 1) substrates by metalorganic molecular-beam epitaxy
K. Uesugi and I. Suemune 103

Photoconductance measurement on TlInGaP grown by gas source MBE
H. Koh, H. Asahi, M. Fushida, K. Yamamoto, K. Takenaka, K. Asami, S. Gonda and K. Oe 107

Growth of Tl-containing III–V materials by gas-source molecular beam epitaxy
M.J. Antonell, C.R. Abernathy, A. Sher, M. Berding, M. Van Schilfgaarde, A. Sanjuro and K. Wong 113

SECTION III. Si/Ge

Nucleation and growth of Ge on Si(1 1 1) by MBE with additional atomic hydrogen irradiation studied by scanning tunneling microscopy
M. Okada, A. Muto, H. Ikeda, S. Zaima and Y. Yasuda 119

Low temperature epitaxial growth by LEPECVD
C. Rosenblad, H.R. Deller, T. Graf, E. Müller and H. von Känel 125
Low-temperature reaction of CH_4 on Si(1 0 0)
A. Izena, M. Sakuraba, T. Matsuura and J. Murota 131

SECTION IV. NEW PRECURSORS

Dynamical approach to the surface reaction of triisobutylgallium (TIBGa) on GaAs(0 0 1) by using molecular beam scattering
J. Cui, M. Ozeki and M. Ohashi 137
Reactivity patterns of stibine and trisdimethylaminoantimony precursors for chemical beam epitaxial growth and etching
J.S. Foord, F.P. Howard, G.S. McGrady and G.J. Davies 144
Growth of InP using TBP and DTBP in metalorganic molecular beam epitaxy
D. Ritter, M. Keidler and H. Heinecke 152

SECTION V. SELECTIVE AREA EPITAXY

Reaction models for the homoepitaxial and selected area growth of GaSb by MOMBE
J.S. Foord, F.P. Howard and G.J. Davies 159
Planar selective area growth of DH laser structures using hydrides, tertiarybutyl and ditertiarybutyl group V precursors in MOMBE
M. Keidler, D. Ritter, H. Baumeister, M. Druminski and H. Heinecke 168
Beam geometrical modelling of CBE on nonplanar substrate
D. Jahan, F. Alexandre and J.L. Benchimol 176
Dopant incorporation behaviour during MOMBE growth of InP on (1 0 0), {1 1 1} and nonplanar surfaces
B. Marheineke, E. Veuhoff and H. Heinecke 183
Vertical stacking of strained InGaAs/GaAs quantum wires by chemical beam epitaxy
S.-B. Kim, J.-R. Ro and E.-H. Lee 191
Nanoscale Si selective homoepitaxial growth observed by scanning tunneling microscopy
K. Fujita, H. Watanabe and M. Ichikawa 197

SECTION VI. CHARACTERIZATION

Surface-roughening processes in GaAs MBE studied by in situ scanning electron microscopy
K. Tanahashi, Y. Kawamura, N. Inoue, Y. Homma and J. Osaka 205
Reflectance anisotropy spectroscopy studies of the growth of carbon-doped GaAs by chemical beam epitaxy
T.B. Joyce, T. Farrell and B.R. Davidson 211
Mapping of Bragg-surface diffraction of InP/GaAs(1 0 0) structure
L.H. Avanci, M.A. Hayashi, L.P. Cardoso, S.L. Morelhão, F. Riesz, K. Rakennus and T. Hakkarainen 220
Spatially resolved characterization of material composition and free carrier concentration by micro-Raman spectroscopy at surface selectively grown layers
W. Limmer, J. Gerster, M. Aigle, J. Porsche, J.M. Schneider, B. Marheineke, H. Heinecke and R. Sauer 225

SECTION VII. PHOTONIC DEVICES

Potential of MOMBE/CBE for the production of photonic devices in comparison with MOVPE
E. Veuhoff 231
Element incorporation in GaInAsP for uniform large area MOMBE
M. Popp, H. Baumeister, E. Veuhoff and H. Heinecke 247
Gas-source MBE of GaInNAs for long-wavelength laser diodes
M. Kondow, T. Kitatani, M.C. Larson, K. Nakahara, K. Uomi and H. Inoue 255
CBE growth of 2%-strained InAsP MQWs for 1.5 μm wavelength laser diodes
H. Sugiura, M. Ogasawara, M. Mitsuhara, M. Itoh and Y. Kondo 260
GRINSCH GaInAsP MQW laser structures grown by MOMBE
H. Baumeister, E. Veuhoff, M. Popp and H. Heinecke 266
Chemical beam epitaxy of integrated 1.55 μm lasers on exact and misoriented (1 0 0)-InP substrates
A. Nutsch, B. Dahlheimer, N. Döhr, H. Kratzer, R. Lukas, B. Torabi, G. Tränkle, G. Abstreiter and G. Weimann 275
MOMBE grown GaInAsP (λ_g = 1.05/1.15 μm) waveguide for laser integrated photonic ICs
H. Künzel, R. Gibis, H. Kizuki, P. Albrecht, S. Ebert, P. Harde, S. Malchow and R. Kaiser 281

Butt-coupling loss of 0.1 dB/interface in InP/InGaAs MQW waveguide-waveguide structures grown by selective area chemical beam epitaxy
C.A. Verschuren, P.J. Harmsma, Y.S. Oei, M.R. Leys, H. Vonk and J.H. Wolter 288
InAsP/InGaAsP periodic gain structure for 1.5 μm vertical cavity surface emitting laser applications
J. Behrend, J.F. Carlin, A.V. Sirbu, C.A. Berseth, A. Rudra and E. Kapon 295
Evaluation of InP/InGaAsP distributed Bragg reflectors grown by chemical-beam epitaxy
A. Rudra, L. Sagalowicz, K. Leifer, J. Behrend, C.-A. Berseth, O. Dehaese, J.F. Carlin and E. Kapon 300
Structural dependence of optical bistability of $In_{0.52}Al_{0.48}As/InP$ type II MQW diodes grown by gas source molecular beam epitaxy
Y. Kawamura, K. Yoshimatsu, A. Kamada, H. Iwamura and N. Inoue 307
Chemical beam epitaxy for high-efficiency InP solar cells
M.F. Vilela, A. Freundlich, C. Monier, F. Newman and L. Aguilar 311

SECTION VIII. QUANTUM WELLS AND INTERFACES

Multiple quantum well compressive strained heterostructures for low driving power all-optical waveguide switches
C. Rigo, L. Gastaldi, D. Campi, L. Faustini, C. Coriasso, C. Cacciatore and D. Soldani 317
Enhanced no-phonon transition in indirect GaAsP/GaP quantum wells by insertion of monolayer AlP for electron localization
T. Sugita, N. Usami and Y. Shiraki 323
Optical and electrical properties of InAlAs/AlAsSb type II quantum well structures grown by molecular beam epitaxy
K. Yoshimatsu, Y. Kawamura, H. Kurisu, A. Kamada, H. Naito and N. Inoue 328
Photocurrent and photoluminescence spectroscopy of $InAs_xP_{1-x}/InP$ strained quantum wells grown by chemical beam epitaxy
C. Monier, M.F. Vilela, I. Serdiukova and A. Freundlich 332
Thermal stability of InP-based structures for wafer fused laser diodes
A.V. Syrbu, J. Behrend, J. Fernandez, J.F. Carlin, C.-A. Berseth, V.P. Iakovlev, A. Rudra and E. Kapon 338

SECTION IX. ELECTRONIC DEVICES

Potential and prospects of CBE technology compared to MBE as production tool for microwave devices
J.Ch. Garcia 343
CBE growth of carbon doped InGaAs/InP HBTs for 25 Gbit/s circuits
J.L. Benchimol, J. Mba, A.M. Duchenois, B. Sermage, P. Launay, D. Caffin, M. Meghelli and M. Juhel 349
AlGaAs/GaAs HBTs with extrinsic base regrowth
Y.M. Hsin, N.Y. Li, C.W. Tu and P.M. Asbeck 355
Room temperature operation of $Ga_xIn_{1-x}P/Ga_{0.47}In_{0.53}As$ resonant tunneling diodes
G.M. Cohen and D. Ritter 359

SECTION X. LOW-DIMENSIONAL STRUCTURES

Formation of InAs quantum dots by metalorganic molecular beam epitaxy using trisdimethylaminoarsenic and bisdimethylaminoarsenicchloride
J. Sato, H. Asahi, T. Tashima, K. Hidaka, K. Yamamoto, K. Asami and S. Gonda 363
In situ composition control of self-organized InGaAs dots
K. Ozasa and Y. Aoyagi 370
Formation of GaAs island by Ga-droplet-induced chemical beam epitaxy
J.-R. Ro, S.-B. Kim and E.-H. Lee 377
Self-organized InAs/GaAs quantum dots grown on (1 0 0) misoriented substrates by molecular beam epitaxy
M.-C. Chen, M.C.H. Liao and H.-H. Lin 383
Growth of strained GaAs islands on (0 0 1) GaP: a RHEED study of quantum wire formation
B.J. Ohlsson and M.S. Miller 387

Author index 392

Subject index 397